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OIL WELL DRILLING TECHNOLOGY

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handled mathematically[20] by the use of an anisotropic index, h, and the values of the ordinate on Fig. 13–25 were modified as follows:

$$\frac{\phi}{\alpha} = \frac{1}{1 - h}$$

The value of h is zero for an isotropic formation, and values between zero and 0.075 were found to explain field observations. It may be observed that in the case of horizontal formations anisotropic formations tend to produce a more vertical hole than do isotropic formations. For example, where h has a value of 0.05, the equilibrium value of ϕ/α becomes 1.0526, shown on Fig. 13–25 as a short dash line. Line 1 intersects this value at an equilibrium deviation of 1 degree from the vertical, as compared to 2.3 degrees for the isotropic formation. If the formations are inclined, then the condition of anisotropy tends to cause the bit to penetrate in a direction normal to the bedding planes. This causes wells to drift upstructure.

Two causes of dog-legs, or sudden bends, in drilled holes are illustrated in Figs. 13–27 and 13–28. In the first case, the direction in which conditions of anisotropy tend to deviate the hole is reversed when passing through the unconformity. The use of a reamer (stabilizer) a short distance above the bit would decrease the severity of the dog-leg. Figure 13–28 illustrates a dog-leg caused by a sudden drop in the drilling weight, which tends to bring the hole rapidly back to the vertical. A gradual reduction in drilling weight, over a distance of fifteen to thirty feet, would cause a gradual bending back toward the vertical and thus avoid forming a severe dog-leg.

Directional Drilling

Directional drilling is used to straighten crooked holes and return them to the vertical, to sidetrack lost tools or obstructions, and to direct the course of the hole in a predetermined path to a predetermined bottom-hole location.[21] Wells are directed to underground locations not under the derrick floor because the surface locations are inaccessible or economically prohibitive. Wells are drilled from the shore to locations under water, and multiple wells are drilled from a single marine drilling platform. Wells are directed under overhanging salt domes in order to avoid drilling through the salt.

Directional drilling requires accurate underground surveys that

[20] *Ibid.*

[21] G. L. Kothny, "Underground Well Surveying, Directed Drilling, Side-wall Sampling, and Polar Core Orientation," *API Drilling and Production Practice* (1941), 76–90.

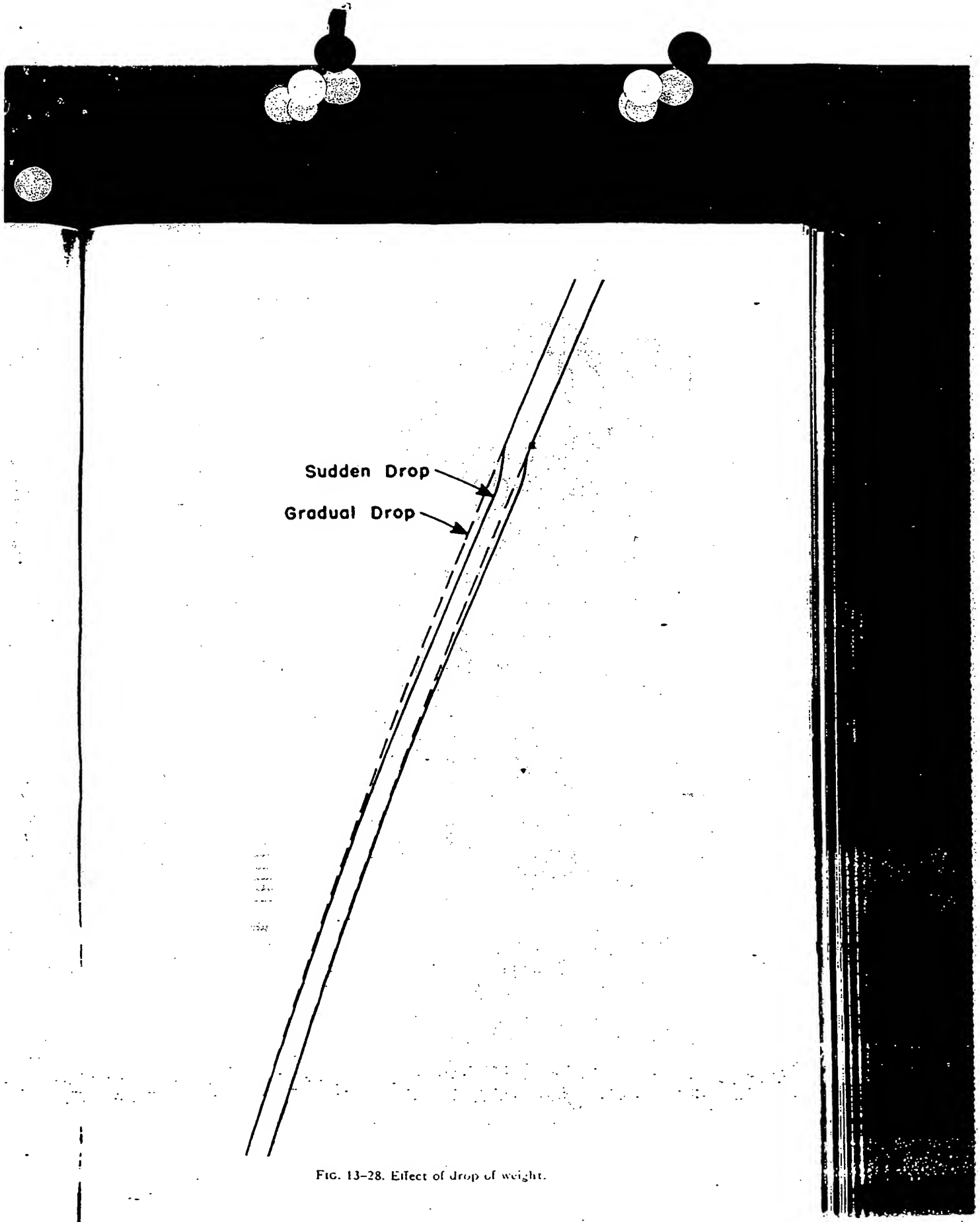

FIG. 13–28. Effect of drop of weight.

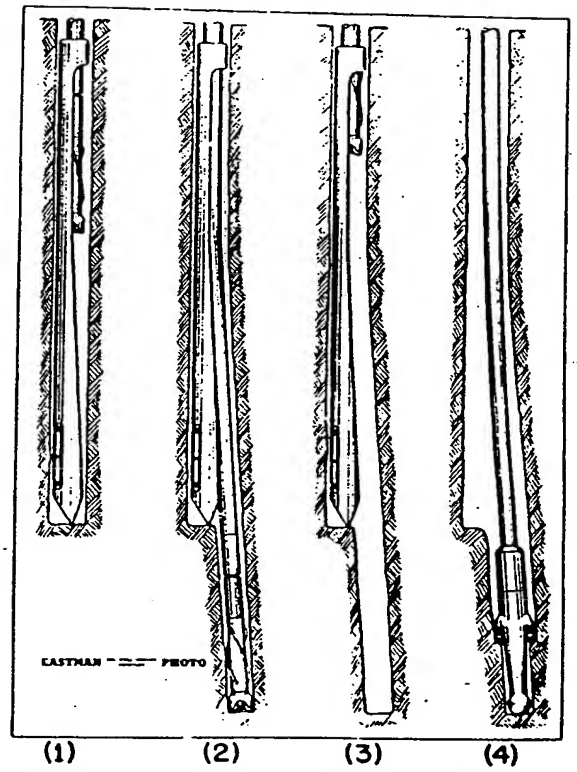

FIG. 13–30. Operation of whipstock: (1) on bottom in oriented position before pin is sheared; (2) drilling assembly in rathole; (3) whipstock in pick-up position; (4) reaming rathole to full gauge with hole opener.

give the amount and direction of hole deviation from the vertical throughout the depth of the well. Pendulums, or plumb bobs, are used to determine the amount of deviation from the vertical where such deviation is less than about 10 degrees. Spherical level boxes are used in cases of greater vertical deviation. The horizontal direction of the deviation is usually indicated by a magnetic compass. The readings of both the pendulum and the compass needle are simultaneously photographed or otherwise recorded at successive depth points in the well. When the magnetic compass is used to determine horizontal direction, the surveying instrument is usually positioned inside of a nonmagnetic stainless-steel drill collar. An earlier practice